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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

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«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық рефеативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық рефеативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылымды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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ASSESSMENT OF THE EFFECTIVE PUBLIC EXPOSURE DOSE DUE TO RADON IN GROUNDWATERS (THE EASTERN REGIONS OF THE REPUBLIC OF KAZAKHSTAN)

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Abstract. *Relevance.* The eastern part of the Republic of Kazakhstan, including the West Siberian, Yenisei–Sayan–Altai, Central Kazakhstan, and Zhetysu–Alatau–Tien Shan hydrogeological regions, is characterized by widespread granitoid massifs and uranium-bearing formations. These geological conditions promote elevated radon concentrations in groundwater, creating potential radiological risks to the population through drinking water consumption. *Objective.* To assess the distribution of radon in groundwater of eastern Kazakhstan, evaluate the associated effective radiation dose to the population, identify areas of elevated radiological risk, and substantiate the need for groundwater radon monitoring.

Methods. Groundwater samples from the major hydrogeological regions of eastern Kazakhstan were analyzed to determine hydrochemical composition, total dissolved solids, and radon activity. Effective annual radiation doses were calculated based on measured radon concentrations, and spatial distribution patterns of radon activity and exposure levels were evaluated. *Results.* The investigated groundwaters are predominantly of the SO_4–Ca and SO_4–Na types, with total dissolved solids ranging from 41 to 62,200 mg/dm³. Radon activity varies from 0.2 to 5,500 Bq/dm³, whereas the background value is 50 Bq/dm³. The calculated effective annual radiation dose ranges from negligible values to 60.5 mSv/year, with an average of 1.5 mSv/year. The recommended safety threshold of 5 mSv/year is exceeded in a considerable number of cases, while more than 30% of groundwater samples contain radon concentrations above the maximum permissible level. The highest radon activities are associated with Paleozoic and Cretaceous–Paleogene aquifers and granitoid intrusions. *Conclusions.* The identified zones of elevated groundwater radon represent areas of increased radiological risk. The obtained results provide a scientific basis for groundwater monitoring, environmental risk assessment, and the implementation of measures to reduce population exposure to radon in the eastern regions of the Republic of Kazakhstan.

Keywords. hydrogeochemistry, radon, effective exposure dose, radon hazard assessment, the Republic of Kazakhstan

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ШЫҒЫС ӨҢІРЛЕРІНДЕГІ ЖЕРАСТЫ СУЛАРЫНДА РАДОННЫҢ БОЛУЫНА БАЙЛАНЫСТЫ ХАЛЫҚТЫҢ ТИІМДІ СӘУЛЕЛЕНУ ДОЗАСЫН БАҒАЛАУ

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Аннотация. *Өзектілігі.* Қазақстан Республикасының шығыс бөлігі, оның ішінде Батыс Сібір, Енисей–Саян–Алтай, Орталық Қазақстан және Жетісу Алатауы–Тянь-Шань гидрогеологиялық аймақтары гранитоидты массивтер мен уран кенденуі кең таралған өңірлер болып табылады. Мұндай геологиялық жағдайлар жерасты суларында радонның жоғары мөлшерде жиналуына ықпал етіп, ауыз су ретінде пайдаланылған жағдайда халықтың радиациялық сәулелену қаупін арттырады. *Мақсаты.* Қазақстан Республикасының шығыс бөлігіндегі жерасты суларында радонның таралу заңдылықтарын бағалау, халықтың тиімді сәулелену дозасын анықтау, радиациялық қаупі жоғары аумақтарды айқындау және жерасты суларындағы радон құрамын тұрақты бақылаудың қажеттілігін негіздеу. *Әдістері.* Шығыс Қазақстанның негізгі гидрогеологиялық аймақтарынан алынған жерасты суы сынамаларының гидрохимиялық құрамы, жалпы минералдануы және радонның көлемдік белсенділігі анықталды. Алынған мәліметтер негізінде халықтың жылдық тиімді сәулелену дозасы есептеліп, радон белсенділігі мен радиациялық әсер деңгейлерінің кеңістіктік таралу ерекшеліктері талданды. *Нәтижелері.* Зерттелген жерасты сулары негізінен сульфатты-кальцийлі және сульфатты-натрийлі гидрохимиялық типтерге жатады, олардың жалпы минералдануы 41–62 200 мг/дм³ аралығында өзгереді. Радонның көлемдік белсенділігі 0,2–5 500 Бк/дм³ аралығында, ал фондық мәні 50 Бк/дм³ құрайды. Халықтың жылдық тиімді сәулелену дозасы болмашы мәндерден 60,5 мЗв/жылға дейін өзгеріп, орташа мәні 1,5 мЗв/жылды құрайды. Ұсынылған қауіпсіз деңгей – 5 мЗв/жыл – көптеген жағдайларда асып түседі, ал жерасты суы сынамаларының 30 %-дан астамында радон мөлшері рұқсат етілген шекті концентрациядан жоғары. Радонның ең жоғары белсенділігі палеозой және бор–палеоген жастағы сулы горизонттарда, сондай-ақ әртүрлі жастағы гранитоидты интрузиялармен байланысты. *Қорытынды.* Жерасты суларында радон мөлшері жоғары болатын және радиациялық қаупі жоғары аймақтар анықталды. Зерттеу нәтижелері жерасты суларының сапасын тұрақты мониторингтеуге, радиациялық қауіпті бағалауға және Қазақстан Республикасының шығыс өңірлерінде халықтың радон әсеріне ұшырауын төмендетуге бағытталған іс-шараларды әзірлеуге ғылыми негіз болады.

Түйін сөздер: гидрогеохимия, радон, тиімді сәулелену дозасы, радон қауіптілігін бағалау, Қазақстан Республикасы

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ОЦЕНКА ЭФФЕКТИВНОЙ ДОЗЫ ОБЛУЧЕНИЯ НАСЕЛЕНИЯ, ОБУСЛОВЛЕННОЙ ПРИСУТСТВИЕМ РАДОНА В ПОДЗЕМНЫХ ВОДАХ (ВОСТОЧНЫЕ РЕГИОНЫ РЕСПУБЛИКИ КАЗАХСТАН)

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Аннотация. *Актуальность.* Восточная часть Республики Казахстан, включающая Западно-Сибирский, Енисейско-Саянско-Алтайский, Центрально-Казахстанский и Жетысу-Алатау-Тянь-Шаньский гидрогеологические регионы, характеризуется широким распространением гранитоидных массивов и ураноносных геологических образований. Такие условия способствуют накоплению радона в подземных водах и создают потенциальную радиационную опасность для населения при их использовании в питьевых целях. В связи с этим оценка пространственного распределения радона и обусловленных им доз облучения имеет важное значение для обеспечения радиационной безопасности населения. *Цель.* Оценить пространственное распределение радона в подземных водах восточной части Республики Казахстан, рассчитать эффективные годовые дозы облучения населения, выявить территории с повышенным радиационным риском и обосновать необходимость мониторинга содержания радона в источниках подземного водоснабжения. *Методы.* Выполнен анализ проб подземных вод, отобранных в основных гидрогеологических регионах восточной части Казахстана. Определены гидрохимический состав, общая минерализация и объёмная активность радона. На основе полученных данных рассчитаны эффективные годовые дозы облучения населения и проанализированы пространственные закономерности распределения радона и уровней радиационного воздействия. *Результаты.* Исследованные подземные воды преимущественно относятся к сульфатному кальциевому и сульфатному натриевому гидрохимическим типам. Общая минерализация изменяется от 41 до 62 200 мг/дм^3. Объёмная активность радона варьирует от 0,2 до 5 500 Бк/дм^3 при условно принятом фоновом значении 50 Бк/дм^3. Рассчитанная эффективная годовая доза облучения изменяется от минимальных значений до 60,5 мЗв/год, составляя в среднем 1,5 мЗв/год. Уровень 5 мЗв/год превышен в значительной части наблюдений, а более 30 % исследованных проб характеризуются содержанием радона выше установленного допустимого уровня. Наибольшая объёмная активность радона выявлена в водах, связанных с палеозойскими и мелово-палеогеновыми водоносными комплексами, а также с зонами распространения гранитоидных интрузий. *Выводы.* Выявлены участки повышенного содержания радона в подземных водах, потенциально характеризующиеся значительным радиационным риском для населения. Полученные результаты могут служить научной основой для организации систематического мониторинга подземных вод, оценки радиационной безопасности источников питьевого водоснабжения и разработки мероприятий по снижению воздействия радона на население восточных регионов Республики Казахстан.

Ключевые слова: гидрогеохимия; подземные воды; радон; объёмная активность радона; эффективная доза облучения; радиационный риск; мониторинг подземных вод

Introduction. The surface and ground water objects for use as the sources of drinking and municipal water supply should be protected from pollution and slugging, provided that the suitability of waters for the indicated purposes is determined on the basis of sanitary and epidemiological conclusions. According to the estimates of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), more than 98 % of public exposure dose is associated with natural radiation sources, which explains increased attention of scientific community to the radiological quality of drinking water.

Studies of radon activity in natural waters, including drinking and mineral waters, are extensively conducted in many regions of the world including the USA, Russia, European and Asia-Pacific countries. Radon concentration is waters can vary from 1 to 100000 Bq/dm³, and in addition to regions with low background values there are sites with anomalously high activity, for example, in Brazil, India, Canada, Türkiye, Iran, etc. (Böhm, 2002; Bertolo, Bigliotto, 2004; Beitollahi et al., 2007; Gurler et al., 2010; Chaudhuri et al., 2010; Abu-Khader et al., 2018; and others). In the regions adjacent to the Russian Federation, many occurrences of radon-rich waters with activity varying between 2 and 25220 Bq/dm³ have been detected (Novikov et al., 2021; Novikov et al., 2022).

In the eastern regions of the Republic of Kazakhstan, water radioactivity is mainly due to the presence of radioactive minerals in age-diverse granitoid massifs, which is confirmed by the discovery of a number of uranium deposits (Grachevskoye, Alutau, Yubileynoye and others) during large-scale exploration works that started as long ago as in the middle of the past century (Fig. 1). Radon-222 is a colorless radioactive inert gas, the product of uranium decay, readily soluble in the groundwaters of endo- and exogenous fracturing zones in granitoid massifs; it does not migrate over large distances from the emanating reservoirs. It has been established in our previous works that it is the interaction in water – rock system that determines the degree of groundwater saturation with radon.

The problem of water radioactivity is especially important for the settlements where groundwaters are used for municipal and drinking water supply. In addition, individual water boreholes are used for water supply in many private homes.

During household water use, radon passes into indoor air, so that its concentration in living and working spaces increases. The highest danger for human health is caused by radon when it is inhaled because the products of its decay staying in the respiratory tract cause ionizing action on the lung tissue cells, which enhances the risk of lung cancer. Oral intake of radon with water or food is less dangerous; however, this route also makes a certain contribution into the total dose received by a person.

In the present study, the contribution from radon, entering homes together with groundwaters, into the total effective public exposure dose is assessed quantitatively, taking into account the inhalation and oral routes of radon intake into the organism. The data obtained allow us to estimate the risk for public health associated with the use of radon-rich groundwaters in the eastern regions of the Republic of Kazakhstan, and to substantiate the necessity of monitoring and control of this radionuclide in water supply systems.

Materials and Methods. Investigation procedure. Investigation is based on the results of retrospective (Voklovgeologiya) and our own measurements of radon activity in groundwaters sampled from the springs and water-supply wells during the field studies in 2025 (see Figure 1).

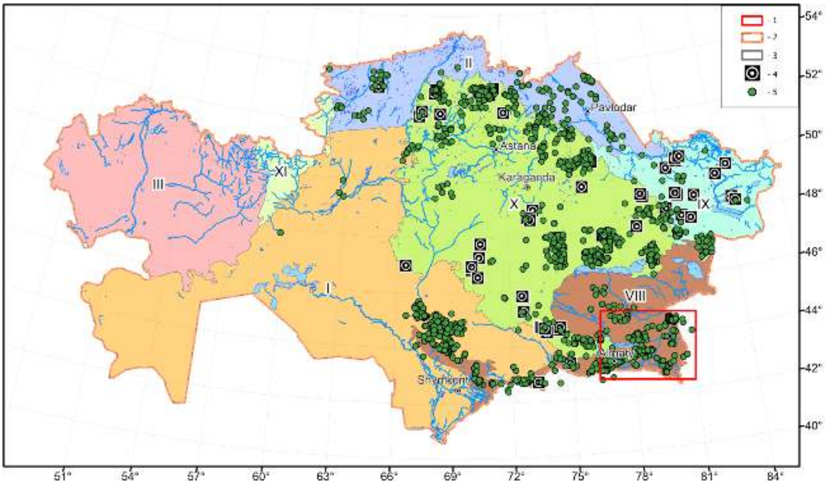

Figure 1. Map of original evidence.
1 – the region of field works in 2025; boundaries: 2 – the Republic of Kazakhstan, 3 – hydrogeological regions; 4 – uranium deposits, 5 – water wells with the data on radon activity. Hydrogeological regions: I – Skifsko-Turakskiy, II – West Siberian, III – Eastern European, VIII – Zhetysu-Alatau-Tien Shan, IX – Yenisei-Sayan-Altai, X – Central Kazakhstan, XI – Taimyr-Ural

Water was sampled into polyethylene containers, and measurement of ^{222}Rn activity was made using alpha-radiometer Alfarad not later than within 2 days after sampling. The total set of geochemical samples over the groundwaters of the Republic of Kazakhstan is represented by the data on 3630 samples. For subsequent analysis, we used 777 samples for which radon activities have been measured (Fig. 2). The effective dose was calculated taking into account oral and inhalation radon intake. The data were mapped (Fig. 3). Calculations were carried out using the equations described in the work by A. V. Kalaido with co-authors (Kalaido et al., 2023), taking into account various parameters affecting the effective dose. The equation to calculate the effective dose received due to the inhalation effect of radon (Einh, mZv/year) released from water during its use is as follows:

$$\mathrm{Einh} = \mathrm{DCF}\left(\frac{\mathrm{CwQwT}}{\mathrm{Vn}}\right)\mathrm{Ft},$$

where DCF is the dose factor for radon inhalation (9·10−9 Zv/(Bq·h·m–3)) (Assessment…, 2002); Cw is radon concentration in water, measured during laboratory studies, Bq/dm3; Qw is daily water consumption, L/day (this value is accepted to be 500 dm3/day for a family of three); T is the coefficient of radon transition from water into air (it is usually equal to 0,1) (Isinkaye, Ajiboye, 2017); V is room volume, m³, which is accepted to be 208 m3: this value was obtained from the average area of individual homes (80 m2) and mean room height 2,6 m; n is air exchange rate, 1/day; F is the factor of radon equilibrium in air (is accepted to be equal to 0,4) (Akhtimankina, Tayurskaya, 2022); t is the time of stay indoor, 6000 h/year (Kononenko, Kormanovskaja, 2015; Kalaido et al., 2023).

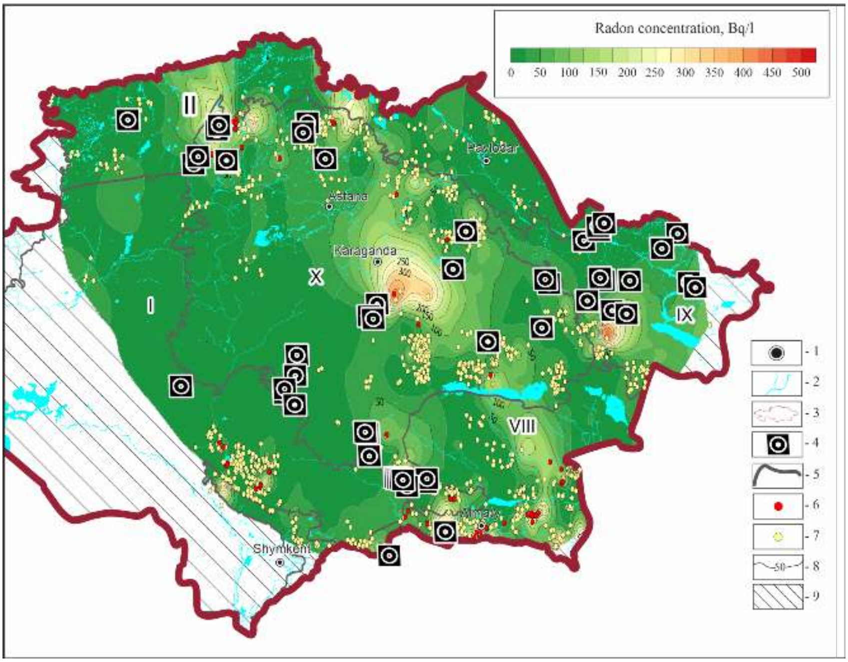

Figure 2. Map of radon activity in groundwaters.
1 – settlements, 2 – hydrographic network, 3 – boundaries of the Republic of Kazakhstan, 4 – uranium deposits, 5 – boundaries of hydrogeological regions, 6 – radon test sites: 7 – radon activity higher than 500 Bq/dm3, 8 – radon concentration isolines, 9 – no data. Hydrogeological regions are listed in Figure 1.

The effective annual dose received from the oral water intake with food (Eing, mZv/year) is determined as

$$\mathrm{Eing} = \mathrm{DCF} \cdot \mathrm{CV},$$

where DCF is the dose factor, Zv/Bq (the recommended value for the oral intake of radon is $3{,}5 \cdot 10^{-9}$ Zv/Bq) (ICRP…, 2012), C is the annual mean radon concentration in water, Bq/dm3; V is the annual volume of water consumed, dm3/year (this value is accepted to be equal to 730 dm3/year, at a rate of 2 dm3/day) (Bem et al., 2014; Isinkaye, Ajiboye, 2017). To estimate radon effect on public health, the total effective dose was used: Einh + Eing.

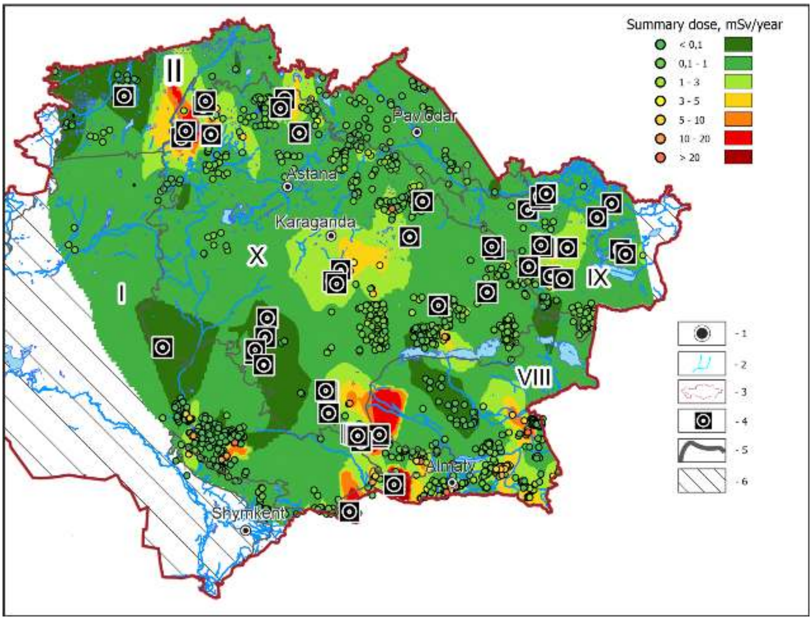

Figure 3. The distribution of effective public exposure doses.
1 – settlements, 2 – hydrographic network, 3 – boundaries of the Republic of Kazakhstan, 4 – uranium deposits, 5 – boundaries of hydrogeological regions, 6 – no data. Hydrogeological regions are listed in Figure 1.

Features of hydrogeological structure. The hydrogeological conditions for all the structures of the territory under investigation have been considered in (Atlas..., 2022; Medeshova et al., 2025). Many factors affect the formation of groundwaters and their propagation, but the factors of prime importance are geological-tectonic features of the hydrogeological structures and the occurrence patterns of permeable rocks, which are natural reservoirs accumulating groundwaters of diverse chemical composition. A close relationship has been established between hydrogeochemical and structural-tectonic conditions, which is evidence that the latter ones affect the formation of major- and trace-component composition of groundwaters. The types of hydrogeological sections characterizing the features of geological structures also belong to the most important factors. Two systems of artesian and non-artesian basins are distinguished within the country: the regions (platforms) with predominant pore-stratal groundwaters (Skifsko-Turanskiy-I, West Siberian-II, Eastern European-III), and regions (orogenic regions) with predominant fracture, fracture-vein and fracture-karst groundwaters, including inter- and intramountain troughs, modern and ancient river valleys with pore and pore-stratal groundwaters (Zhetysu-Alatau-Tien Shan-VIII, Yenisei-Altai-Sayan-IX, Central Kazakhstan-X, Taymyr-Ural-XI) (see Figure 1). The first-order basins are distinguished within the boundaries of regions.

Geochemical features and radon distribution in groundwaters

The waters under investigation were divided into five groups according to the age of water-bearing sediments (Table 1). The major ion composition is presented in Figure 4,a. The Gibbs' diagrams [Gibbs, 1970] show that the chemical composition of waters is formed with contributions from atmospheric precipitation, the transition of elements from rocks during weathering, and evaporation. It has been determined that most points fall in the terrigenous rock weathering field (figure 4b-d). Continental salting processes are broadly manifested in the upper hydrodynamic zone.

Group I includes waters that occur within the ungraded Paleozoic sediments, these waters belong to the sulfate calcium and sulfate sodium type. Their salinity is 60-62200 mg/dm3 (2210,6 mg/dm3 on average), their hydrogen-ion exponent is neutral weakly alkaline (pH 6,05-9,3). The activity of radon (222Rn) varies within a broad range from 0,3 to 5098,6 Bq/dm3, with the average total effective dose being 1,66 mZv/year.

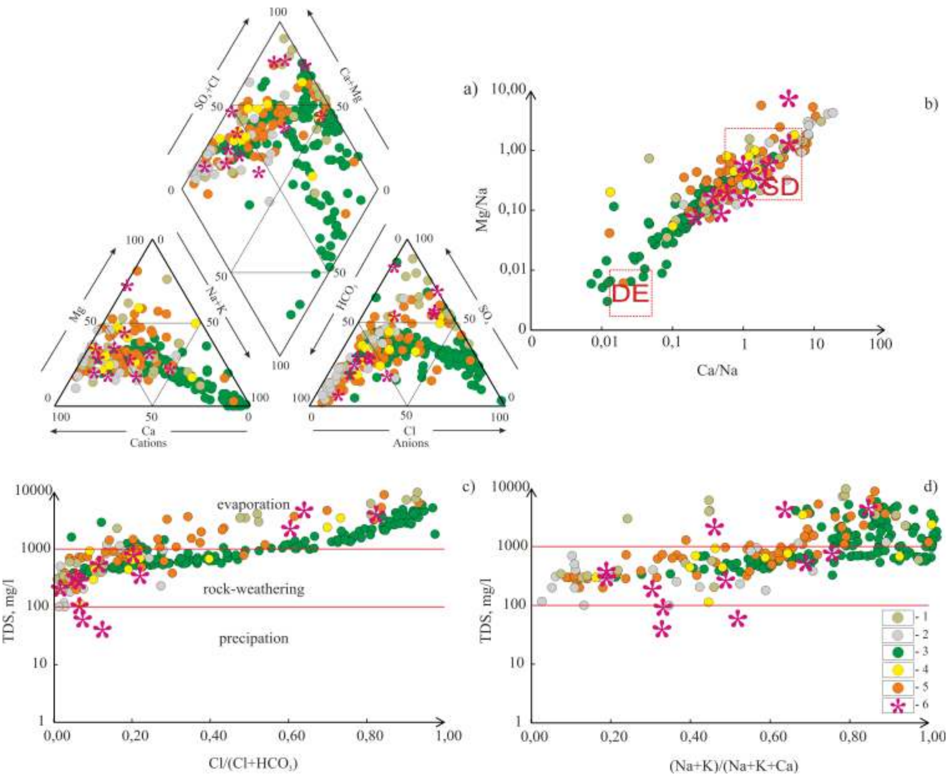

Figure 4. Piper diagram of groundwater composition for the eastern regions of the Republic of Kazakhstan (a), distribution of geochemical coefficients depicting the mechanisms controlling the chemical composition of natural waters (according to Gibbs [1970]) (b-d).
Aquifers: 1 – ungraded Pre-Cambrian rocks, 2 – the Cambrian-Carboniferous sediments, 3 – Cretaceous-Paleogene sediments, 4 – Neogene sediments, 5 – Quaternary sediments; 6 – water-bearing zones of exogenous and tectonic fracturing of diverse-aged magmatic formations.

In water-saturated rocks of the Cambrian-Carboniferous age (group 2), the groundwaters with predominant hydrocarbonate calcium composition are determined. The average salt content is 2077,8 mg/dm3 (varying within the range from 100 to 44100 mg/dm3), pH varies from weakly acidic to weakly alkaline (from 6,5 to 8,4). Radon activity varies from 1,97 to 5550 Bq/dm3, with the average total effective dose 1 mZv/year.

Table 1. Groundwater saturation with radon, effective dose.

Group No.	Group	M, mg/dm3	pH	Rn, Bq/ dm3	Effective dose, mZv/year	Number of samples
1	PZ	60-62200 2210,6(140)	6,05-9,3 7(112)	0,3-5098,6 152,1(182)	0,004-55,6 1,66(182)	182
2	€-C	100-44100 2077,8(127)	6,5-8,4 7,2(76)	1,97-5550 95,5(139)	0,02-60,55 1(139)	139
3	K- ₽	305-5849 1422(162)	7-8,9 8,1(160)	0,2-5400 141(167)	0,003-58,9 1,55(167)	167
4	N	113-3500 966,6(14)	7-8,8 7,9(12)	10-388,5 93(16)	0,1-4,2 1,01(16)	16
5	Q	168-12618 1422(97)	6,4-8,5 7,5(82)	122-704,5 65,8(121)	0,02-7,7 0,7(121)	121
6	Age-diverse intrusives	41-17000 1047(128)	6,2-8,25 7,3(59)	3,7-4954 187,4(148)	0,04-54 2(148)	148

Note: the range is indicated in the numerator, the average value is in the denominator, and the number of samples per each measurement is shown in parentheses. The values exceeding the effective dose limit are printed in bolt type.

Group 3 (the most numerous) is represented by the waters from the Cretaceous-Paleogene aquifers. The geochemical sample set is represented by a great variety of chemical types, with the predominance of chloride-sulfate sodium composition. Total salinity varies within a wide range from 305 to 5849 mg/dm3 (1422 mg/dm3 on average). The pH varies from neutral to weakly alkaline (from 7 to 8,9). The waters of this group are distinguished by high radon activity, reaching 5400 Bq/dm3 (while the average value is 141 Bq/dm3). The average total effective dose is 1,54 mZv/year.

Group 4 includes the groundwaters of the Neogene age. These waters are characterized by the diversity of chemical types, however, the hydrocarbonate-sulfate type with mixed cationic composition. The average total salinity for the waters of this group is 966,6 mg/dm3 (varying between 113 and 3500 mg/dm3). These waters are weakly alkaline (pH 7,8–8). The maximal activity of radon is 388,5 Bq/dm3, the average activity being 93 Bq/dm3; the effective dose is 1,01 mZv/year.

Group 5 includes the groundwaters of the Quaternary sediments. The chemical type of these waters is mainly hydrocarbonate-sulfate with mixed cationic composition. Total salinity varies from 168 to 12618 mg/dm3 (the average value is 1422 mg/dm3). The pH varies from weakly acidic to weakly alkaline (6,4-8,5). Radon activity has been determined to vary from 122 to 704,5 Bq/dm3, the average effective dose is 0,7 mZv/year.

All fracture-vein waters of intrusive formations represented by age-diverse granites and granodiorites have been united in group 6. Two prevailing kinds of groundwaters are distinguished within this group: hydrocarbonate-sulfate and sulfate-chloride with mixed cation composition, with the average total salinity equal to 1047 mg/dm3. The pH of waters varies between 6,2 and 8,25, from weakly acidic to weakly alkaline. The average activity of radon is 187,4 Bq/dm3, while the maximal value is 4954 Bq/dm3. The average effective dose is 2 mZv/year.

In general, neutral and weakly alkaline waters dominate (pH 6,5-8,9). The TDS of groundwaters varies within a broad range from 41 to 21600 mg/dm3. The most substantial data scattering and the highest salinity are observed in group 1, relatively low values are characteristic of group 2. In all other groups, the average TDS values are close to each other. Radon activity varies from 0,2 to 5550 Bq/dm3, extreme high values were detected in the groundwaters of group 3, high values also are characteristic of group 1, and waters of other groups exhibit approximately similar radon activity values.

According to monitoring results (Fig. 2), within the Zhetysu-Alatau-Tien Shan hydrogeological region radon activity varies within a broad range from 2 to 5098 Bq/dm3, with the average value equal to 230 Bq/dm3. The lowest radon activity is detected in the Yenosei-Sayan-Altai region: from 3,7 to 400,5 Bq/dm3 (40,3 Bq/dm3 on average). In the Skifsko-Turanskiy region, radon activity is within the range from 0,2 to 5400 Bq/dm3, the average value being 124 Bq/dm3, and in the Cewntral Kazakhstan region it varies from 0,3 to 5550 Bq/dm3 (106 Bq/dm3 on average).

The calculated background activity of radon for the region under inevestigation is 50 Bq/dm3, which does not exceed the action level; nevertheless, the maximum permissible concentration was exceeded by more than 30 % of samples (Figure 4).

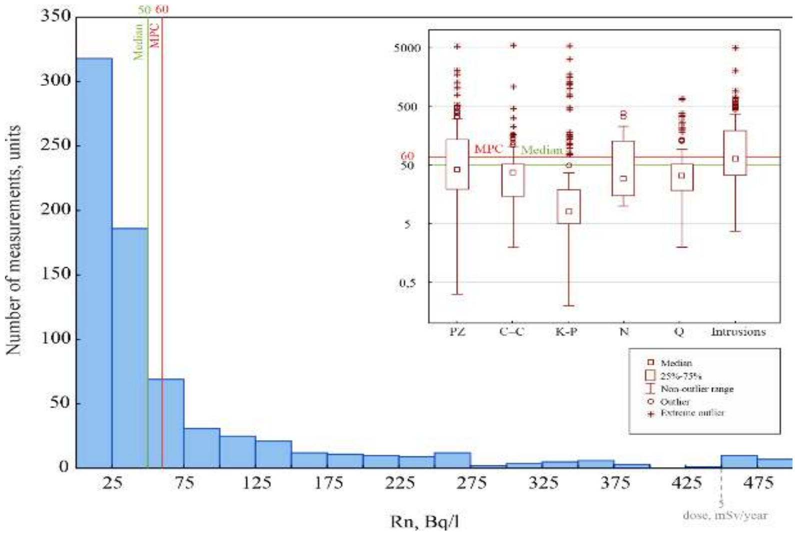

Figure 5. The distribution histogram and radon activity variation diagrams for the groundwaters.

Analysis of the diagrams shown in Figure 5. provides evidence of the presence of regions where the permissible level of radon in groundwaters is exceeded substantially, which is well seen in the diagram of radon activity variation in groundwaters, with extreme high concentrations detected. The maximum radon activity (up to 5000 Bq/dm3) is observed in the groundwaters of ungraded Paleozoic, Cretaceous-Paleogene and magmatic rocks.

Results and Discussion. According to calculations, the effective annual dose for 88% of the objects does not exceed the world average value (2,4 mZv (National…, 2009)). However, for 5% of the studied objects the effective exposure dose exceeds 5 mZv/year and reaches 50-60 mZv/year, which means that using water from these sources is dangerous, this situation requires immediate precautions aimed at improvement of the radiological conditions and establishment of the regular monitoring of water sources (Hygienic…, 2011). Substantial exceedance of the permissible effective dose, with radon activity above 4000 Bq/dm3, is observed in the spring and well near Aksuek settlement in the Moynykum district of the Zhambyl Region of Kazakhstan, as well as in the wells and springs of the Sozak district of the Turkestan Region (Fig. 3). Attention should be paid to the fact that radon in water is not a sole source of ionizing radiation: substantial contribution is made by radon entering with the soil air, gamma radiation directly from the rocks and some construction materials, and other natural sources.

Conclusions. Groundwaters mainly of sulfate calcium and sulfate sodium types with TDS varying from 41 to 62200 mg/dm3 are widespread over the territory under investigation. Their chemical composition is formed due to the two dominating processes: terrigenous rock weathering and continental salting.

According to monitoring results, radon activity at the territory under study varies within a very broad range: from 0,2 to 5550 Bq/dm3 with the average value equal to 121 Bq/dm3 and background value 50 Bq/dm3. The effective public exposure dose due to radon is 0,002 to 60,5 mZv/year.

In 88% of the objects, the effective annual dose from natural sources does not exceed the world average value, 2,4 mZv, however, in 5% of samples the effective exposure dose exceeds 5 mZv/year and reaches 50-60 mZv/year, thus it is dangerous to use water from these sources, and this situation requires immediate precautions aimed at improvement of the radiological environment and establishment of regular monitoring of water sources.

The largest contribution into the total effective dose is made by radon inhalation, so efficient means to decrease its harmful action are indoor ventilation, preliminary water storage in open vessels for natural decrease of radon activity as a result of radioactive decay.

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